AD A115905

Technical Report 538

DESIGN GUIDELINES AND CRITERIA FOR USER/OPERATOR TRANSACTIONS WITH BATTLEFIELD AUTOMATED SYSTEMS

VOLUME V: BACKGROUND LITERATURE

Robert N. Parrish, Jesse L. Gates, and Sarah J. Munger
SYNECTICS CORPORATION

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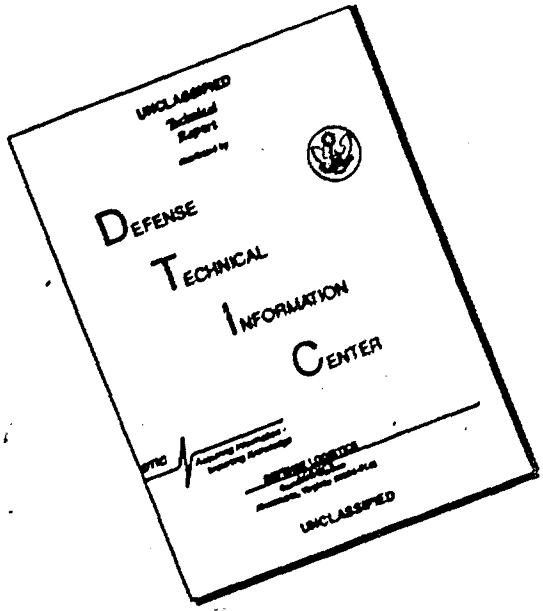

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Technical Report 538	2. GOVT ACCESSION NO. AD A115935	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Design Guidelines and Criteria for User/Operator Transactions with Battlefield Automated Systems Volume V: Background Literature		5. TYPE OF REPORT & PERIOD COVERED Interim Oct 1979-Feb 1981 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Robert N. Parrish Jesse L. Gates Sarah J. Munger		8. CONTRACT OR GRANT NUMBER(s) MDA903-80-C-0094
9. PERFORMING ORGANIZATION NAME AND ADDRESS Synectics Corporation 10400 Eaton Place Fairfax, VA 22030		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263744A793
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eise-hower Ave., Alexandria, VA 22333		12. REPORT DATE February 1981 13. NUMBER OF PAGES 41
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Dr. Raymond C. Sidorsky, of the Human Factors Technical Area, ARI, is the Contracting Officer's Representative for this project.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Battlefield automated systems	Human-computer interaction
Design criteria	System analysis
Design Guidelines	Transaction Feature Analysis
Functional Standardization	User/operator transaction

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document is one of a series in the Final Report of Phase I in a project to develop design guidelines and criteria for user/operator transactions with battlefield automated systems. The report is organized in five volumes as follows:

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

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Item 20 (Cont'd)

I. Executive Summary (RR 1320)
II. Technical Report (TR 536)
III. In-Depth Analyses of Individual Systems
A. Tactical Fire Direction System (TACFIRE) (RP 81-26)
B. Tactical Computer Terminal (TCT) (RP 81-27)
C. Admin/Log Automated Systems (RP 81-28)
D. Intelligence Information Subsystem (IISS) (RP 81-29)
IV. Provisional Guidelines and Criteria (TR 537)
V. Background Literature (this report)

Volume I presents a succinct review of activities and products of the project's first phase. Volume II contains a technical discussion of the project's objectives, methodologies, results, conclusions, and implications for the design of user/operator transactions with battlefield automated systems. Volume III documents analyses of four unique battlefield automated systems selected to represent different stages of system development and different Army functional areas. Volume IV presents provisional guidelines and criteria for the design of transactions. Volume V provides a brief review of selected literature related to guidelines and criteria.

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Technical Report 538

DESIGN GUIDELINES AND CRITERIA FOR USER/OPERATOR TRANSACTIONS WITH BATTLEFIELD AUTOMATED SYSTEMS

VOLUME V: BACKGROUND LITERATURE

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Office, Deputy Chief of Staff for Personnel
Department of the Army

February 1981

Army Project Number
2Q263744A793

Human Performance Effectiveness
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FOREWORD

The Human Factors Technical Area of the Army Research Institute (ARI) is concerned with helping users and operators cope with the ever increasing complexity of the battlefield automated systems by which they acquire, transmit, process, disseminate, and utilize information. Increased system complexity increases demands imposed on the human interacting with the machine. ARI's efforts in this area focus on human performance problems related to interactions with command and control centers, and on issues of system design and development. Research is addressed to such areas as user-oriented systems, software development, information management, staff operations and procedures, decision support, and systems integration and utilization.

An area of special concern in user-oriented systems is the improvement of the user-machine interface. Lacking consistent design principles, current practice results in a fragmented and unsystematic approach to system design, especially where the user/operator-system interaction is concerned. Despite numerous design efforts and the development of extensive system user information over several decades, this information remains widely scattered and relatively undocumented except as it exists within and reflects a particular system. The current effort is dedicated to the development of a comprehensive set of Human Factors guidelines and evaluation criteria for the design of user/operator transactions with battlefield automated systems. These guidelines and criteria are intended to assist proponents and managers of battlefield automated systems at each phase of system development to select the design features and operating procedures of the human-computer interface which best match the requirements and capabilities of anticipated users/operators.

Research in the area of user-oriented systems is conducted as an in-house effort augmented through contracts with uniquely qualified organizations. The present effort was conducted in collaboration with personnel from Synectics Corporation under contract MDA903-80-C-0094. The effort is responsive to requirements of Army Project 2Q263744A793, Human Performance Effectiveness and Simulation, and to special requirements of the U.S. Army Combined Arms Combat Developments Activity (CACDA), Fort Leavenworth, Kansas.

JOSEPH ZEIDNER
Technical Director

DESIGN GUIDELINES AND CRITERIA FOR USER/OPERATOR TRANSACTIONS WITH BATTLEFIELD AUTOMATED SYSTEMS VOLUME V: BACKGROUND LITERATURE

EXECUTIVE SUMMARY

Requirement:

To develop a comprehensive set of human factors guidelines and criteria for the design of user/operator transactions in battlefield automated systems for use by human factors specialists and system proponents, managers, and developers.

Procedure:

To augment data collected during analyses of a series of battlefield automated systems, selective literature relevant to the development of human factors guidelines and criteria for the design of user/operator transactions was reviewed. The literature review effort was limited primarily to recent ARI publications and to reports containing guidelines which might be incorporated into the final product of the project.

Findings:

This literature review demonstrated that research results are generally inadequate to support design of good user/operator transactions in automated systems. In addition, experimental investigations and other research efforts have not kept sufficient pace with technological development to provide an adequate data base for generation of guidelines and criteria applicable to the rapidly changing user/operator transaction environment.

Utilization of Findings:

Findings from the analysis of individual systems may be useful to proponents in specifying user/operator requirements for future system evolution. In this project, the findings were incorporated in a data base on human factors requirements which provided the "real world" foundation for development of the provisional guidelines and criteria presented in volume IV of this report. The provisional guidelines and criteria will be utilized as the basis for development of the prototype handbook.

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INTRODUCTION

The U.S. Army is actively engaged in development of automated systems to meet anticipated requirements, including battlefield mission requirements. More than 60 automated systems currently in a concept definition, development, or production stage depend upon the design and accomplishment of effective user/operator transactions--the user/computer interface, procedures, and techniques--to permit effective utilization and accomplishment of mission objectives.

The Army Research Institute for the Behavioral and Social Sciences (ARI) "provides scientific and technical support to the human resources needs of the Army, using techniques and disciplines of behavioral and social science (*Zeidner, et al*, 1979, p. 28)[1]. ARI conducts in-house research and supports grant and contract research in the following general areas: personnel and manpower, education and training, training devices and simulation, and human factors in training and operational systems. This research is, in part, in support of automated systems development.

The Human Factors Technical Area of ARI is concerned with effective utilization of battlefield automated systems (BASs), especially because of the increasingly complex demands of systems which are used to acquire, transmit, process, disseminate, and utilize information. The Human Factors unit is particularly concerned with the demands placed on human performance related to the human-computer interaction. ARI's human factors research efforts have been concerned with software development, topographic products and procedures, tactical symbology, user-oriented systems, information management, staff operations and procedures, decision support, and sensor systems and utilization.

Because the ARI human factors efforts are so closely akin to the needs of this project, some of the pertinent research products have been reviewed to demonstrate how this literature can contribute to the development of

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[1]/Zeidner, Joseph. *Research themes in behavioral and social sciences.* U.S. Army Research Institute for the behavioral and social sciences, Alexandria, Virginia, 1979.

guidelines and evaluation criteria for the design of user/operator transactions in battlefield automated systems. Several characteristics of this literature review should be made clear:

a. The review was conducted as a demonstration of how ARI documents and other research reports support project activities; no attempt has been made to integrate or contrast results obtained through experimental investigations. A full literature review, to be conducted during the second phase of the project, will more exhaustively incorporate relevant ARI and other research efforts.

b. With few exceptions, only very recent reports have been included in the review. Much earlier work also has significance for the development and presentation of human factors guidelines and criteria.

c. Some reports have been included because they contain guidelines which could almost directly be incorporated into the intended final product of the study effort; others are included because they provide information which can contribute to or convert to guidelines or criteria.

The organizing structure for presenting the ARI literature review is that employed to date throughout the project for presenting information about the systems reviewed and for the development of guidelines and criteria--categories of design features affecting user/operator transactions. These categories are listed in Table 1. ARI research reports are presented on the following pages.

1. CONTROL METHODS

1.1 Command Languages

Operating Systems, Inc. *MIQSTURE: An experimental online language for army tactical intelligence information processing.* ARI Technical Report No. TR-78-A-25, July 1978. (AD A064 323).

In its search for ways to address the demands for increased complexity in the user-machine interface of BAS, ARI supported this effort for development of an online language for Army tactical intelligence information processing. *MIQSTURE* (Mixed Initiative Query Structure with Task and User Related Elements) is an attempt to provide a user-machine dialogue in which the computer

Table 1

Categories of Design Features Affecting User/Operator Transactions with Battlefield Automated Systems

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1. CONTROL METHODS

    1.1 Command Languages
    1.2 Menus
    1.3 Function Keys
    1.4 Hybrid Methods
    1.5 Prompted HELPS

2. DISPLAY FORMAT

    2.1 Fixed Alphanumeric Displays
    2.2 Variable-Length Alphanumeric Displays
    2.3 Graphic Displays
    2.4 Highlighting

3. DATA ENTRY AND HANDLING

    3.1 Information on Legal Entries
    3.2 Unburdening of Input
    3.3 Interrupts and Work Recovery
    3.4 Manipulating Stored Data

4. MESSAGE COMPOSITION AIDS

    4.1 System Design Features
    4.2 Format for Alphanumeric Messages
    4.3 Graphic Messages

5. DATA RETRIEVAL ASSISTANCE

    5.1 Query Method
    5.2 Query Structure

6. GLOSSARIES

    6.1 Standard Terms
    6.2 Character Sets and Labels
    6.3 Glossary Availability and Use
    6.4 Abbreviation and Coding

7. ERROR HANDLING

    7.1 Prevention
    7.2 Detection
    7.3 Feedback
    7.4 Correction/Recovery

8. USER/OPERATOR CONFIGURATION

    8.1 Operator(s) Only
    8.2 Operator(s) and User(s)
    8.3 Combined User/Operator
    8.4 User and Operator Chains

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has an active role instead of the dialogue being initiated completely by the user. MIQSTURE allows the computer to prompt the user through complex tasks, provides task specific effort feedback, and alerts the user to "other" information in the data base.

Development progressed through 4 stages:

a. Requirements definition based on documentation and interviews.

b. Concept development based on the requirements definition.

c. Preparation of detailed design specifications for 6 subsets of the language to demonstrate operating characteristics and potential.

d. Evaluation of the language primarily to determine which design goals had been reached and for the subset for querying and manipulating tabular data in the data base, comparison with the data base language SEQUEL.

The developers claim MIQSTURE has the following advantageous characteristics:

a. Adaptivity to change through the use of specially designed formats for defining new capabilities and use of a keyboard substrate language to provide flexibility for new and emergent circumstances.

b. Sensitivity to the elements and stages of interactive tasks through separate display of interaction status and history, separate incrementing of transaction and query numbers, a multistream dialogue which allows interleaving of tasks at a given terminal, and a capability for loading "knowledge" of detailed task structure into the system to permit the mixed initiative capability.

Evaluation of MIQSTURE was carried out by comparisons and ratings provided by a panel of experts on 7 factors: level of development, training factors, speed factors, power factors, accuracy factors, staffing ease, and user acceptability. The developers conclude that the preliminary/partial development and demonstration of MIQSTURE has achieved the desired effectiveness for accomplishing intelligence processing tasks.

1.2 Menus

No reports in this category were reviewed.

1.3 Function Keys

No reports in this category were reviewed.

1.4 Hybrid Methods

No reports in this category were reviewed.

1.5 Prompts/HELPS

No reports in this category were reviewed.

2. DISPLAY FORMAT

2.1 Fixed Alphanumeric Displays

No reports in this category were reviewed.

2.2 Variable-Length Alphanumeric Displays

Baker, J.D., Mace, D.J., & McKendry, J.M. *The transform operation in TOS: assessment of the human component.* ARI Technical Research Note No. 212, August 1969 (AD 697 716).

The transform operation is defined as the transformation of raw data for input into storage devices. This study explored the time and errors involved in message format selection. A sample of 14 military and civilian personnel working on the TOS (Tactical Operating System) development selected a format for 47 situation messages out of the 43 available formats. Data collected were: time to make the selection, the frequency of incorrect format selection, and the certitude of the selection (a 7 point scale from "absolutely uncertain" to "absolutely certain"). One group used a job-aid to assist in the format selection. No differences were found between the job-aided and the standard groups on any of the above measures.

Menu format selection time was 49.8 seconds per message. Other data indicated that during peak periods, the G3 could expect to receive a message every 70 to 90 seconds. With the time to merely select a message format at about 50 seconds, the G3 would quickly be overloaded in peak periods. A 22 percent error rate in format selection was obtained in the selection of formats for reportedly simple messages. A detailed analysis of the errors revealed a confusion created by an irrelevant correspondence between message content and message category titles. The mean certitude was almost identical for the two groups (5.5 for the job-aided group and 5.7 for the standard group), indicating that the particular job aid provided failed to aid performance.

The authors noted (page 15) that "taken together, the error rate and the time data...lead to the conclusion that the transformation process is potentially a major problem in the experimental TOS." To eliminate format selection errors, they suggest a structured training program or a set of mnemonic descriptions for message titles, drawing attention to the relevant differences in the purpose of the various message formats. They speculate that the most likely error (erroneous selection of the "relay" message format) will result in a communications function only when the information should have been input into the data base. They suggest a scrutiny of the existing formats with a goal of reducing their number. (NOTE: the current and most recent successor system to TOS, TCS/TCT, in using only four basic message formats, appears to have taken their advice to heart.)

Nystrom, C.O., and Gividen, G.M. *Ease of learning alternative TOS message reference codes.* ARI Technical Paper No. 326, September 1978. (AD A061 697).

In work closely allied to that of Baker, Mace, and McKendry (1969) and Strub (1971), these researchers set out to assess the changes to the DEVTOS formats (in the formats provided for TOS[2]) recommended by the *ad hoc* committee

established for that purpose.[2] This effort was dedicated to determination if these changes contribute to the learnability of the codes developed for the TOS^2 formats. The article is also valuable to this project for its presentation of code design strategies and instructional strategies associated with specific code designs.

The rules for generating the two code sets are as follows:

a. <u>DEVTOS-like codes--2 alphas, 1 numeric (LL#).</u> The first two letters represent the message category and the digit represents the type of action. The first letter distinguishes friendly, enemy, and "common" message categories, with an exception, F, for aircraft-related message categories. The second letter is arbitrarily assigned within the friendly or enemy categories, but is always an "A" for the common message. The action code (#) uses 1 - 6 for the six action codes, but exceptions are allowed with common messages where 0, 8, and 9 replace 1, 2, and 3.

b. <u>TOS^2 codes--4 alphas (LLLL).</u> The first three letters form an acronym of the message title. The fourth letter represents the action. Examples of the two message code types are presented in Table 2.

Table 2

Sample DEVTOS and TOS^2 Message Codes

	Code Elements					
	Message Title Code		Action Code		Message Reference Code	
Message Title	DEVTOS	TOS^2	DEVTOS	TOS^2	DEVTOS	TOS^2
G-2 Messages						
Enemy Unit Status - Add	EA	EUS	1	A	EA1	EUSA
Enemy Situation Data - Query	EC	ESD	4	Q	EC4	ESDQ
G-3 Messages						
Air Control Mesaure - Change	UH	ACM	2	C	UH2	ACMC
Spot Report - Special Processing	US	USR	5	P	US5	USRP

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[2]/In anticipation of the Development Tactical Operating System (DEVTOS) by TOS^2 (the Tactical Operable Segment Tactical Operating System), the Combat Developments Command (CDC) directed the formation of an *ad hoc* committee to (a) recommend revisions to the formats and (b) evaluate these revisions. The committee also established the following recommendations: (a) consolidation of message formats, (b) use of variable field data entry, (c) map reference coordinate "packing," and (d) use of a new message reference code system.

Participants were 20 enlisted and 40 officer personnel with no prior experience in using the formats. Enlisted personnel were randomly assigned to one of two G2 message code sets (LL# or LLLL). Officers were randomly assigned to one of two G2 or one of two G3 code sets (also LL# or LLLL). There were 26 G2 message format titles and 57 G3 message format titles. Participants performed at a computer terminal one at a time. Initially they reviewed a tabular presentation of message titles from which to learn message format titles. The task was to provide the correct message reference code from the message title and action code. Error feedback informed the participant of the correct code when an error was committed. The "learning" criterion was a "perfect pass"--correct completion of all message titles in the message set.

The following were the independent variables:

a. Code type (LL# or LLLL).

b. G2 or G3 list.

c. Rank of the participant (enlisted versus officer).

The dependent variables were as follows:

a. Percent of message reference codes input with one or more errors.

b. Number of "passes" through the code list (learning time).

c. Time to input a message code (averaged over all codes and all passes).

d. Analysis of error rate by character position (for officer participants only).

LLLL codes were clearly superior to LL# codes in both learning rate and error rate. The mean time to input a message reference code did not differ by code type: a time limit of 20 seconds to respond was permitted and average response time was about 5.5 to 6.5 seconds. Enlisted personnel took significantly longer to learn the codes than officer personnel (despite the high enlisted personnel GT score). For both percentage of errors and average input time, differences were not significant, but only marginally so at .053 for mean percentage of errors.

Analysis of errors by character position demonstrated that seven of the new code's characters were associated with excessively high error rates. Four approaches to reducing the error rate and instructional strategies associated with these approaches are suggested by the authors for exploration:

a. <u>Partial code revision</u>--modification of only those codes associated with excessive error rate, the change bringing these codes into closer acronymity.

b. <u>Three word message titles</u>--forced three letter acronyms.

c. <u>Variable length acronymic code</u>--requires message titles to consist of three words or less with no ambiguities. However, involves change to only 8 message types versus change to 16 message types for option b.

d. <u>Three letter code based on first and last words of the message title</u>--the code uses the first two letters of the first word and the first letter of the last word. This accommodates message titles of two words or more and requires change of only 1 message title.

The authors conclude that the TOS' message reference code (LLLL) is clearly better than the DEVTOS code (LL#) and they suggest a further experiment and predict that approaches b., c., and d., would all be better than a.).

Moses, F.L., and Potash, L.M. *Assessment of abbreviation methods for automated tactical systems.* ARI Technical Report No. 398, August 1979. (AD A077 840).

As part of a continuing effort to provide efficient vocabularies and message structures for BASs, ARI evaluated alternative methods for creating abbreviations of military terms. Moses and Potash establish the following criteria for abbreviations: (p. 1)

a. Quickly and easily discriminated from other abbreviations in a particular system.

b. Easily decoded and remembered.

c. Compatible with a variety of different system configurations.

Their investigation focused on the design and evaluation of procedures for creating abbreviations; their review of the literature led them to conclude that: "Clearly, a variety of suggestions exist for shortening single as well

as multiple word items. However, no generalizable recommendation has emerged for methods which generate abbreviations that are preferred, easily decoded, and used with minimal learning." (p. 2)

Participants, 50 enlisted military personnel with diverse backgrounds, performed three tasks:

a. Preference rating--judging how well single military terms are represented by abbreviations generated under the following five methods:

   1. Data Element Dictionary (DED)--representing current Army practice.[3]

   2. Simple truncation--starting from the right end of the word, dropping off characters until the required length is obtained.

   3. Truncation--2nd letter out--elimination of the 2nd character followed by simple truncation, as above.

   4. Contraction--vowels out--retention of the 1st and 2nd characters, removal of vowels and H, W, Y (from right to left) until required length is obtained, supplementing with simple truncation, as necessary.

   5. Contraction--frequent letters out--retention of the 1st character, elimination of letters (from right to left) on the basis of frequency of occurrence (highest frequency eliminated first) until the required length is obtained.

b. Decoding--writing the original term from the abbreviation. 60 abbreviations were generated on the basis of the 5 methods described above. (Different terms, random assignment of terms to blocks of participants, etc., permitted a modified Latin Square design.)

c. Encoding--generation of an abbreviation for each of 60 terms; 30 terms were new, 30 were used in task a.).

For task a., preference rating on a 10-point scale, showed that abbreviations prepared by contraction--vowels out and by simple truncation were

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[3]/The DED is the result of the TRADOC Data Element Standardization Program and was developed to meet the needs of the Tactical Operable Segment Tactical Operations System (TOS[2]), the All Source Analysis System (ASAS), and the Tactical Fire Control System (TACFIRE).

preferred over other methods, with the DED and truncation--second letter out being least preferred. For task b., decoding, liberal scoring (allowing spelling errors) and strict scoring were applied separately to previously seen items (in task a.) and not previously seen items. Five factor ANOVA (based on the modified Latin Square design) for the liberal and strict scores and comparison of mean scores supported simple truncation as the superior method with the DED being the worst technique overall. For encoding task c.), simple truncation again appeared a frequently used technique; but, the DED, in contrast to tasks a. and b., scored well.

These results support simple truncation as the method for providing a high percentage of acceptable abbreviations for use as data element codes in BASs. The authors, however, in exploring user/use variations of these results and in playing these results against those obtained by other researchers, offer the following tempered conclusions:

> *Simple truncation is an easy-to-use method that generates a high proportion of consistently preferred and easily decodable abbreviations for single words. This method should benefit system designers by reducing the time needed to produce many good abbreviations for use as data element codes. Such abbreviations presumably should benefit users by reducing input time and errors in interactions with battlefield systems. However, the abbreviations produced by simple truncation are not intended to replace commonlu accepted abbreviations and are not likely to be judged acceptable in all cases.* (p. 14)

2.3 Graphic Displays

No reports in this category were reviewed.

2.4 Highlighting

No reports in this category were reviewed.

3. DATA ENTRY AND HANDLING

3.1 Information on Legal Entries

No reports in this category were reviewed.

3.2 Unburdening of Input

Alderman, I.N., Ehrenreich, S.L., and Bindewald, R. *Recent ARI Research in Battlefield Automated Systems.* (In press.)

(The authors' abstract follows.)

This paper reviews ARI research designed to improve the data entry process. The first and second section of the paper describes the data entry process in general as well as in the context of a specific battlefield automated system, the Tactical Operating System (TOS). Because it was used as an exemplar of the data entry process, TOS played an important role in the development of improved data entry procedures. The third section of the paper reviews the findings and conclusions of the many ARI research projects concerned with data entry. Among the areas covered in ARI's research program are:

a. How to format and display data entry information.

b. What safeguards can be developed to reduce the number of operator errors made and/or accepted by the system.

c. What kinds of operator job aids can be developed to improve performance.

d. How to improve operator training.

e. How to make the system's message codes easier to use and more memorable.

f. How to improve the design of keyboards.

The forth section of the paper reports on efforts to analyze the cause of operator errors. This section also discusses the development of a simulation of the data entry process. The simulation is intended to facilitate system design by permitting the inexpensive evaluation of alternate data entry procedures. The fifth section presents a general discussion of the problems that have been encountered by the ARI research program. Also included here is a discussion on how this program might be improved in the future. The final section of the paper summarizes the operational implications of ARI's research results.

Granda, T.M. *An application of human factors concepts to an interactive computerized personnel record-keeping system.* ARI Research Report No. 1233, January 1980.

(The author's summary follows.)

To reduce the burden of inefficient record-keeping systems, the U.S. Army plans to convert many of its manual and semiautomatic record-keeping systems to interactive, real-time systems. To obtain the optimal level of hardware/software complexity, to meet operator and user requirements, and to keep system costs, system complexity, and operator training and skill requirements at a reasonable level, a careful analysis and application of appropriate behavioral, man-computer interface guidelines are required. A working version of a potential interactive real-time record-keeping system (the Standard Installation/Division Personnel System, SIDPERS) was created to provide a hands-on demonstration of input/output procedures and software techniques that can provide assistance to operators/users.

The behavioral techniques and procedures in the demonstration (e.g., feedback, error detection and correction, prompting, variable entry format, variable input modes) were integrated with user and operator requirements to produce an efficient interactive record-keeping system. It was successfully demonstrated that the human-factored, interactive system aided several types of users in a variety of ways. The system functioned as an instructive aid to the inexperienced user and as a memory aid to the experienced user by informing the user: where to find data and information; how to input the data; when errors occurred, what type of errors they were and how to correct them; what certain terms meant; and what inputs were acceptable to the computer. The computer served as a retrieval clerk for those users who needed access to information residing in the computer. The computer also acted as an organizer for the processing of SIDPERS transactions, retrieval of information, and alteration of the transaction clerk displays.

Fields, A.F., Maisano, R.E., and Marshall, C.F. *A comparative analysis of methods for tactical data inputting.* ARI Technical Paper No. 327, September 1978. (AD A060 562).

This study extends ARI's efforts to improve data input beyond its previous explorations regarding the man-machine interface (Alderman, 1976),

individualized training techniques (Gade, Fields, and Alderman, 1978), computer prompting and instruction (Strub, 1975), and using on-line inputting with verification (Strub, 1971). In contrast to the earlier efforts, however, this study focuses on inputting procedures as these affect operator speed and accuracy.

Four methods of data input into a TOS format, each using automatic tabbing, were studied:

a. Typing codes into the message format. Message format appears on the screen; operator fills in appropriate codes referring to a dictionary of valid codes, as needed. Computer rejects illegal entry; operator must provide valid entry to continue. Cursor moves to next item when correct entry made.

b. Typing with error corrector. Same as typing, above, except computer forms a series of hypotheses about the error and then, having "decided" on the correct entry, the computer presents the entry on the screen. If the operator accepts the entry, it is input by a key to signal acceptance. If not accepted, the operator has a key to signal retyping of the entry. If the machine cannot form a hypothesis, an error message appears on the screen and the operator retypes an entry.

c. Menus. Map coordinates, dates, and cardinal numbers are typed in. All other data entered by selecting the item from an alphabetically or logically ordered menu via a trackball. When typing required, instruction to type replaces the menu. If invalid entry typed in, item rejected and valid entry provided as in data input type a., above.

d. Typing with autocompletion and English option. Same as input type a. with the following exceptions:

    1. The English definition can be entered instead of the code.

    2. When operator feels enough characters are entered to identify the entry, depression of a key causes the autocompletion program to take over. If unique match made within the valid entry list, the autocompletion feature finishes the entry. If no unique match possible, the program asks for more characters.

The measures (dependent variables) were format completion time, the number of errors per format, the frequency of use of the autocompletion function, the frequency of use of full English instead of codes, the frequency of backspacing and typing over, and the stated preference among the input methods.

Participants were 32 enlisted personnel randomly assigned to the four input groups. Thirty-six free text messages were divided into four sets of nine messages each, with each message set balanced for types of subject, sources, restrictions, unit identification, and difficulty during pilot testing. Each first message of each message set was a practice message.

On the basis of both mean number of errors per message and fewest errors per input method, the input types ranked (from best to worst) as follows: menus, typing with error corrector, straight typing, and typing with autocompletion. Differences among the input methods were significant. No differences were found among input methods on the basis of mean time to input messages. On the basis of fastest time, the input types ranked as follows: typing with error corrector, straight typing, and menu selection. (The authors' speed prediction was as follows: autocompletion, menu selection, error corrector, and straight typing.) When preferences were compared to performance time and errors (using a coefficient of agreement), there is chance agreement or a slight negative agreement. Except for input by menu selection, backspacing was used with approximately the same frequency across participants for correcting an entry, correcting spelling, or correcting an invalid entry. In about one-third of its attempts, the error corrector could not arrive at an entry. Participants used the autocompletion feature only for better than only one-half of their possible opportunities; the autocompletion of codes was incorrect about 4 percent of the time and autocompletion of English was incorrect a little better than 9 percent of the time.

The authors conclude that menus should be used for data input since they permit fewer errors and do not significantly increase input time. Provision of a menu-based system with a menu-override option for experienced users is suggested. Error correctors, autocompletion and full English option are not warranted for general use, in their judgment.

3.3 Interrupts and Work Recovery

No reports in this category were reviewed.

3.4 Manipulating Stored Data

No reports in this category were reviewed.

4. MESSAGE COMPOSITION AIDS

4.1 System Design Features

Griffith, D. *TACFIRE OT [illegible] human factors evaluation.* ARI Research Problem Review 79-6, March 1979.

(The author's brief of the report follows.)

Requirement:

This research was conducted as a human factors evaluation of the Tactical Fire Direction System (TACFIRE) command and control system for the field artillery. This report supplements the TCATA OT [illegible] test report. It provides a human factors evaluation of equipment, tasks and operating procedures, training, and personnel selection requirements.

Procedure:

A variety of techniques were used in this human factors evaluation. Questionnaires were developed and administered; these addressed specific human factors issues. These questionnaires were supplemented by interviews and by pertinent data from TCATA questionnaires and data collection forms. Performance assessments were also obtained for individual operators at the Artillery Control Console and on the Digital Message Device. Personnel records and formal course grades were used to analyze personnel selection requirements.

Findings:

The battalion S-280 shelter is regarded as unacceptable by battalion Fire Direction Center personnel. The major problem areas are the shortage of space within the shelter, the configuration of equipment within this limited space, the quality of the air, and the noise level. Noise levels are in excess of MIL-STD-1474A.

With the exception of the Digital Message Device and the Digital Plotter Map, there is widespread acceptance of individual TACFIRE equipments.

Although operators maintain that their tasks, on the average, are easy, the consensus of operators is that TACFIRE training must be conducted

frequently if skills are to be maintained. Estimates of time required to train averaged about 2 days a week at the computer Fire Direction Center and Variable Format Message Entry Device sites and 1 day a week at Digital Message Device sites. Moreover, indications are that more emphasis needs to be placed on maintenance training.

Operators who use the standard (QWERTY) keyboard should know how to type. The Army Classification Battery appears to provide a cost-effective means of selecting individuals for TACFIRE schooling.

Utilization of Findings:

The findings of this report will serve as the human factors input to TCATA and OTEA for their evaluation of the TACFIRE system. These findings will also be sent to the Army Field Artillery School (USAFAS) for their impact on training and personnel selection requirements.

4.2 Format for Alphanumeric Messages

No reports in this category were reviewed.

4.3 Graphic Messages

Bersh, P., Moses. F.L., and Maisano, R.E. *Investigation of the strength of association between graphic symbology and military information.* ARI Technical Paper No. 324, September 1978. (AD A064 260).

The authors contend that dissatisfaction with conventional symbology drives investigation of symbology in terms of "clarity, simplicity, consistency, and adequacy for computer generation" (page 1) and that "there is little or no empirical evidence available for accepting any new approaches or for retaining conventional symbology" (*ibid*). Their investigation is an attempt to allow common cultural influences to form more or less stereotypical associations--"Natural" associations, in their terminology. They explored the association of simple graphic codes or symbols with verbal concepts.

The graphic symbol set was kept simple and consisted of:

a. Seven symbol sets (e.g., circles, lines, colors, shading, bars) with each set varying in a single characteristic (e.g., size of circle, number of lines, width of bars).

b. Eight geometric forms (diamond, trapezoid, rectangle, circle, triangle, parallelogram, and ellipse).

c. Eight "stick" symbols (e.g., arc, bracket, arrow, cross).

The verbal concepts explored included:

a. Eight information categories (importance, accuracy, firepower, unit level, friend/enemy, range, and concentration).

b. Nine military branch designations (infantry, armor, field artillery, mechanized infantry, signal, engineer, air defense artillery, cavalry, and aviation).

c. Three general military function terms (service support unit, maneuver unit, fire support unit).

Participants were two groups of enlisted personnel (114 and 137 persons respectively) with limited prior exposure to military symbology. The first group was presented a set of graphic symbols followed by a set of verbal concepts. Their task was to rank order the verbal concepts according to how well they represented the symbol. The second group's task was the reverse of the first group's; i.e., to rank order the symbols according to how well they represented the concepts.

Four criteria were established to determine the strongest symbol-concept associations:

a. A statistically best mean rank (i.e., statistically different from any other association).

b. A mean rank statistically better than any other association.

c. A first place ranking by the greatest number of participants.

d. Fulfillment of either a. or b. and of c. for both symbol-concept and concept-symbol associations.

Only three symbol-concept associations were found to be high strength and no ambiguity:

a. <u>Numerosity</u> (the number of lines) and <u>unit length</u>--which supports the current military coding scheme for designating units.

b. <u>Color</u> and <u>danger</u>--other strong color associations; e.g., with friend/enemy, accuracy, importance indicate that color symbolizes a broader concept than danger, perhaps "threat".

c. Square and service support--this association is much stronger in the concept-symbol direction than in the symbol-concept direction.

Moderate and minimal levels of association were also examined but they provide no clear-cut guidance for our study with respect to guidelines and criteria for user/operator transactions with BASs in that:

a. Results of the exploration are not without ambiguity/confusion.

b. The study approach limits findings to specific conditions explored rather than to general demonstration of design principles.

The authors suggest that their ranking method is appropriate for preliminary comparisons and that their data provide suggestions for use in modifying current symbology systems. They also suggest, however, that Thurston's paired-comparison procedure would provide more refined measurement than theirs--albeit at increased time and cost.

5. DATA RETRIEVAL ASSISTANCE

5.1 Query Method

No reports in this category were reviewed.

5.2 Query Structure

Ehrenreich, S.L. *Query language: design recommendations derived from the human factors literature*, ARI Technical Report No. 484 (in press).

(The author's abstract follows.)

The existing human factors literature on query languages is both sparse and scattered. This paper seeks to collect and review that literature. The first section of the paper introduces the subject of query languages. In the second and third sections, the topics of natural and formal query languages are respectively discussed. These two types of query languages are reviewed with the objective of determining their potential for expanding the population of computer users. The fourth section considers some general issues pertinent to both types of

logical quantifiers, the user's concept of data organization, mixed initiative dialogues, and the use of abbreviations. Methods for experimentally evaluating specific query language features and research on person-to-person communication are also discussed here. To focus the findings reported in the preceding sections, the fifth section summarizes the implications of the research performed to date. Next, the sixth section presents possible new research which would be of value to the designers of Army tactical information systems. The paper concludes with two appendices. Appendix A discusses human factors review papers concerned with the design of interactive systems. Appendix B presents a compendium of design recommendations directed towards the system designer.

(Appendix B is replicated below.)

APPENDIX B

QUERY LANGUAGE: A COMPENDIUM OF DESIGN RECOMMENDATIONS

These recommendations were compiled from the literature review that is presented in the main body of this paper and from additional sources. In some instances, the recommendations that are presented here go beyond what can be empirically substantiated. These recommendations are not to be considered immutable. Instead, they represent the author's opinion as to what guidelines might be thoughtfully offered at the present time to a system designer.

Recommendations: General

Data Organization

1. The organization of the data base that is presented to the users should match the organization perceived to be natural by the users. The users' natural organization can be discovered through experimentation or by survey.

2. Casual users should not be presented with a multitude of models for representing the data base. A single representation of the data base should be sufficient for the total range of user needs. A multiplicity of data base structures only tends to confuse the casual user.

Quantifiers

3. A query language should minimize the use of quantification terms (e.g., "some," "all"). People have great difficulty in using quantifiers unambiguously. Exceptions to this rule are the quantifiers "no" and "none." When quantifiers are required, the system should have the user choose the desired quantification statement from a set of statements that are designed to maximize their distinctiveness.

Evaluating Language Options

4. Test major query language features prior to adopting them. The text of this paper provides a description of experimental procedures that can be used in deciding between alternative design options.

Feedback of the Query

5. Prior to the execution of a user's query, the computer should rephrase the query and display it for user acceptance. This assures that the user's intended meaning has been correctly interpreted by the computer. (Skilled users should be able to suppress this feature if so desired.)

Abbreviations

6. The method of simple truncation should be used in forming abbreviations for terms; e.g., deleting all but the first three to five letters of the words. The value of this technique is markedly increased when it is uniformly applied (with the possible exception of words which have commonly known abbreviations). Allowance must be made for different words resulting in the same abbreviation when truncated. User understanding of how the abbreviations are formed is valuable.

Dialogue Transactions

7. The system's messages to the user should be in a directly usable form and provide prompts or reminders of the current state of transaction development. The user should not have to refer back to previous transactions in order to determine the present states of the system. Lengthy sequences of transactions should be recapped periodically.

8. When the system displays information, "it should be in the form needed at that point even if the format is different from that provided in the data base or (from) when it was originally entered. For example, in a payroll or cost-accounting system salaries may be stored in hourly rates, but if the current activity requires monthly or yearly rates, the computer should make the required transformation and display accordingly."

9. Users should be able to easily modify a request that is revealed to be incorrect. In particular, they should be able to move backwards through a dialogue sequence in order to change an entry. Introducing such a change should not require re-entry of all the correctly entered material.

10. A small proportion of queries usually accounts for a high proportion of the user's activities. These queries should be designed for greatest ease of accomplishment.

11. Some user queries require a long response time. The computer should acknowledge the receipt of a query and should later indicate that a response is available.

Specific Recommendations:
Formal Query Languages

Layering

12. The features of a query language should be partitioned into groups or layers. The easiest layer should be able to stand alone and is intended for users of limited sophistication or limited need. The layers should then increase in complexity for use by more sophisticated personnel. Such a procedure will broaden the base of users.

Semantic Confusion

13. Avoid the use of operators such as "or more" and "or less" (e.g., do not require the user to convert "over 50 years old" into "51 or more"). People have difficulty using these operators correctly.

14. Query language operators should not be given semantically similar names (e.g., "SUM" and "COUNT"). To avoid confusion, operators should be given names that are distinctive and self-explanatory.

Term Specificity

15. For inexperienced users, the use of global terms (e.g., general terms which subsume a number of specific terms) is not recommended unless the specific terms of information subsumed under the global terms are retrieved together frequently. The availability of global terms does increase the speed of data entry (i.e., typing) but does not affect accuracy.

Specific Recommendations:
Natural Query Languages

Clarification Dialogue

16. Natural query language systems should be capable of carrying out a "clarification dialogue." Users will frequently input poorly stated queries and it is not sufficient for the system to simply reject them. Instead, the system should be capable of guiding the user through a dialogue which will result in the formulation of a proper statement.

Quasi-Natural Languages

17. Quasi-natural languages should be considered as design options in situations where it is neither possible to teach a formal query language to potential users nor is it feasible to develop a natural query language. Quasi-natural languages are English-like in structure but they are not capable of truly "understanding" the text's meaning. For a quasi-natural language to be applicable, the system's task should be narrow and well defined. Examples of the use of a quasi-natural language are given in the text.

6. GLOSSARIES

No reports in this general category were reviewed.

7. ERROR HANDLING

7.1 Error Prevention

Mace, D.J., Harrison, P.C., Jr., and Seguin, E.L. *Prevention and remediation of human input errors in ADP operations.* ARI Technical Report No. 395, August 1979. (AD A081 730).

This document goes into detailed discussion about input errors, ways to overcome them, and procedures for analyzing the cost-benefit of circumventing them. An example illustrative of the thinking process involved in applying the MAUM[3] cost-benefit analysis to TOS is presented. (Their example is not

[3]/MAUM is the Multi-Attribute Utility Measurement presented in: Edwards, W., Guttentag, M., and Snapper, K. in *Handbook of evaluation research, volume 1*, E.L. Streuning and Marcia Guttentag, eds. Sage Publications, Beverly Hills, California, 1975.

nearly so concrete as the one provided by the original authors who apply the procedure to the planning process of the Office of Child Development and use real data.)

Of greater interest, particularly at this stage of our own project effort, is the attention to the sources of data input errors and their prevention and detection. Table 3 presents the authors' summary of error types, causes, and alternatives for prevention and detection.

Gade, P.A., Fields, A.F., and Alderman, I.N. *Selective feedback as a training aid to on-line tactical data inputting.* ARI Technical Paper No. 349, November 1978. (AD A061 789).

This study, one of a series focused on improvement of data entry, is an experimental investigation into the effectiveness of various instructional strategies for overcoming error in data entry. The intended special application of the research is the MIOD (Message Input Output Device) operator of the Army's Tactical Operations System (TOS).

Earlier research reviewed by Alderman (1975) focused on improved data input (reduced time and error) by reallocating the inputting functions/tasks and by development of job training aids. Strub (1971) demonstrated increased MIOD operator accuracy by use of a CRT for direct data input and decreased entry time by use of a computer-generated format on the CRT (1975). He suggested that an automated training program, incorporating input aids with a response-sensitive training instructional strategy, would improve training effectiveness. This study investigates that hypothesis.

These investigators hypothesized that a response-sensitive instructional strategy, in conjunction with computer-generated feedback, would have the following desirable effects on MIOD operator training, as compared to more conventional training strategies:

a. More rapid progress through the training material.

b. Improved transfer of training to operational environments.

Participants, 71 enlisted personnel, took part in a training session and a transfer-testing session. Each participant completed 21 messages during the training session. In the testing session, participants completed

Table 3

Error Types, Causes and Alternatives for Prevention and Detection

ERROR TYPE	CAUSE OF ERROR	PREVENTION AND DETECTION
OMISSION OF MESSAGE SET	Lack of knowledge of user/operator Incompatibility between source document and input dialogue Misplaced document Operator failure	User/operator selection User/operator training Revise procedures - horizontal distribution of input activities Revise source document formats Revise input formats
OMISSION OF DATA ELEMENT GROUP	Incompatibility between source document and input dialogue Skip a line or lose a page	Revise procedures - vertical distribution of input activities Revise source document formats Revise input formats
OMISSION OF DATA ELEMENT	Improper presumption of default values Element input into wrong location Loss of place in source or preformatted document Loss of place in dialogue with system, e.g. cursor position	Use formats with explicit labels Display default values Conditional error checking Conditional formatting Interactive dialogue
VALID CODES/RESTRICTED ITEMS		
Verbal Errors (Glossary)	Incorrect recall Incorrect recognition Transcription errors	Input language Expanded definitions Conditional, probabilistic, or adaptive error checking
Quantitative Errors	Incorrect scale conversions Data input with incorrect scale Incorrect rounding of numbers Careless transcription, including character transposition and decimal placement	Editing process Formatting Conditional, probabilistic, or adaptive error checking
INVALID CODES/RESTRICTED ITEMS		
Verbal Errors - Incorrect Abbreviations	Incorrect recall Incorrect recognition Typographic mistake	Input language Menu selection Displayed codes Glossary display or "HELP" routines
Verbal Errors - Incorrect Location	Typographic mistake Format generated confusion	Formats with explicit labels Data base update Conditional formatting Question and answer dialogue Menu selection Displayed codes
Quantitative Errors - Incorrect Location	Typographic mistake Format generated confusion	Formats with explicit labels Data base update Conditional formatting Question and answer dialogue
Quantitative Errors - Illegal Entry	Incorrect scale conversion Data input with incorrect scale Incorrect rounding of numbers Careless transcription, including character transposition and decimal placement	Editing processes Formatting
UNRESTRICTED ITEMS		
Equivocal Coding (Same code used with two or more meanings)	Coding conventions inadequate Data element too short	Improper coding conventions Lengthen data element Provide glossary of previous entries Data base update Expanded definitions
Variable Coding (Two or more codes used with same meaning)	Coding conventions inadequate Misspellings Spacing Number of coded entries which must be recalled	Improve coding conventions Provide glossary of previous entries Data base update Expanded definitions

as many messages as possible, up to a miaxmum of 43. Participants were assigned randomly to four levels of training feedback, as follows:

a. Minimum feedback--informed only of error on last entry, no correction.

b. Edit feedback--error message, use of legal entry tables from which to correct the error.

c. Remedial feedback--error message displaying both the incorrect and correct entry, and participant error correction.

d. Response-sensitive feedback--same as remedial, except that after 3 correct consecutive entries for a particular element of a particular type of format, automatic fill of the element by the computer.

There were also two conditions of transfer-testing--no feedback and edit feedback.

Speed and accuracy were the performance measures. Response-sensitive training proved effective in reducing training time and was as effective as other training strategies in reducing error rates. However, since the study does not suggest that response-sensitive training will assist in catching errors that escape error detection routines and does not improve the error rate, the decision of whether or not to implement response-sensitive training should be based on the trade-off between the cost of training development and the benefit of reduced training time.

7.2 Error Detection

No reports in this category were reviewed.

7.3 Error Feedback

No reports in this category were reviewed.

7.4 Error Correction/Recovery

No reports in this category were reviewed.

8. USER/OPERATOR CONFIGURATION

Fink, C.D., and Carswell, W.A. *Integrated personnel and training information for TRADOC system managers (TSM). Technological Caps.* ARI Research Report No. 1238, February 1980.

(The authors' abstract follows.)

The Integrated Personnel Support (IPS) model outlines the procedures that should be followed during the development of personnel and training subsystems for new materiel systems. This report identifies some of the technological problems that must be solved before benefits from the application of the IPS model can be achieved. These problems or "technological gaps" were identified during an extensive literature review for, and the subsequent development of, a handbook for TRADOC System Managers (TSM).

Most of the technological gaps related to deficiencies in procedures for estimating training and personnel requirements, and for the development of training strategies, during Phases I and II of the Army's Life Cycle System Management Model (LCSMM). Specifically, there was found to be an absence of satisfactory techniques for (a) deducing training and personnel requirements from materiel characteristics; (b) identifying excessive human resources demands stemming from materiel concepts; (c) identifying functions most appropriately performed by equipment, by persons, or by a man-machine combination; (d) generating task analytic data during Phase I of the LCSMM; (e) identifying high-risk training tasks during Phase I of the LCSMM; (f) indicating appropriate training strategies before actual hardware is developed; and (g) describing human resources data/requirements/constraints in terms that are meaningful to design engineers.

Additional ARI Literature to be Reviewed

Alderman, I.N. Tactical Data Inputting: Research in Operator Performance and Training. *Proceedings of the Second National Symposium on the Management of Data Elements in Information Processing.* Washington, D.C.: NBS/ANSI, 1976.

Ciccione, D.C., Samet, M.G., and Channon, J.B. A Framework for the Development of Improved Tactical Symbology. *ARI Technical Report No. 403*, August 1979. (AD A076 017)

Colson, K.R., Freeman, F.S., Mathews, L.P., and Stettler, J.A. Development of an Informational Taxonomy of Visual Displays for Army Tactical Data Systems. *ARI Research Memorandum No. 74-4.*, February 1974. (AD A082 951)

Granda, T.M. A Comparison between a Standard Map and a Reduced Detail Map within a Simulated Tactical Operations System (SIMTOS). *ARI Technical Paper No. 274*, June 1976. (AD A028 752)

Granda, T.M. An Evaluation of Visual Search Behavior on a Cathode Ray Tube Utilizing the Window Technique. *ARI Technical Paper No. 293*, February 1978. (AD A053 352)

Hemingway, P.W., and Kubala, A.L. A Comparison of Speed and Accuracy of Interpretation of Two Tactical Symbologies. *ARI Technical Report No. 389*, July 1979. (AD A075 428)

Hemingway, P.W., Lubala, A.L. and Chastain, G.D. Study of Symbology for Automated Graphic Displays. *ARI Technical Report No. TR-79-A18*, May 1979. (AD A076 916)

Mawrocki, L.R. Word Abbreviations in Man-Computer Communication Systems. *ARI Working Paper HF 79-04*, June 1979.

Modiste, B.R., Michel, R.R., and Stevens, J.W. Initial Strategies for the Tactical Operations System (TSO) Support of the Command and Control Process. *ARI Technical Report TR-78-A16*, June 1978.

Moses, F.L., and Maisano, R.E. User Performance Under Several Automated Approaches to Changing Displayed Maps. *ARI Technical Paper No. 366*, June 1979. (AD A073 726)

Negroponte, N., Herot, C., and Weinzapfel, G. One point touch input of vector information for computer displays. *ARI Technical Report No. TR-78-TH3*. (NTIS No. ADA064278)

Patten, S.M. An Inductive Taxonomy of Combat Intelligence Data. *ARI Research Memorandum 74-14*. December 1974. (AD A076 802)

Potash, L.M. Effects of Retrieval Term Specificity on Information Retrieval From Computer Based Intelligence Systems. *ARI Technical Paper No. 379*, July 1979. (AD A072 312)

Sidorsky, R.C. Alpha-Dot: A New Approach to Direct Computer Entry of Battlefield Data. *ARI Technical Paper No. 249*, January 1974. (AD 774 841)

Sidorsky, R.C. Source Data Automation via the Alpha-Dot Tablet: A Feasibility Study. *ARI Working Paper No. 79-07*. June 1979.

Sidorsky, R., Gellman, L.H., and Moses, F.L. Survey of Current Developments in Tactical Symbology: Status and Critical Issues. *ARI Working Paper No. HF-79-03*, May 1979.

Siegel, A.I., Leahy, W.R., and Wolf, J.J. A Computer Model for Simulation of Message Processing in Military Exercise Control and Evaluation Systems. *ARI Technical Report TR-77-A22*. October 1977.

Strub, M.H. Evaluation of Man-Computer Input Techniques for Military Information Systems. *ARI Technical Research Note No. 226*, May 1971.

Strub, M.H. Automated Aids to On-Line Tactical Data Inputting. *ARI Technical Paper No. 262*, February 1975. (AD A016 359)

NON-ARI LITERATURE

Literature in the public domain was explored for the purpose of finding information appropriate to the development of guidelines and criteria and, indeed, to identify useful sources of guidelines and criteria. This section of this report is not intended to be a "review" of the literature in the traditional sense. Rather, its purpose is to identify documents which provide human factors guidelines and evaluation criteria for the design of user/operator transaction in battlefield automated systems or which could substantively contribute to the development of such guidelines and criteria.

Gagne, R.M., *et al. Psychological principles on system development*, Holt, Rinehart and Winston, New York, 1963.

This volume remains a basic and often quoted source of information for system design. Its emphasis on the human component of the system, and particularly on the development of that component, is especially cogent to the objectives of this project. In addition to providing much information concerning the design of the human-machine interface, the text will be particularly useful to the project in defining the appropriateness of guidelines for different stages of system development.

Ramsey, H.R. and Atwood, M.E. *Human factors in computer systems: A review of the literature*, Science Applications, Inc., Englewood, Colorado, 21 Sepember 1979. (Technical Report SAI-79-111-DEN).

Ramsey, H.R., Atwood, M.E., and Kirshbaum, P.J. *A critically annotated bibliography of the literature of human factors in computer systems*, Science Applications, Inc., Englewood, Colorado, 31 May 1978. (Technical Report SAI-78-070-DEN).

Ramsey and Atwood conducted a broad survey of the literature on human factors in computer systems to assess the state of knowledge in the area. Their objectives were to:

a. Determine whether or not that knowledge is adequate to support the development of a human factors guide to the design of interactive computer systems.

b. Present a descriptive and critical literature review with respect to the issue of design guidelines.

Their conclusions with respect to the feasibility, potential utility, and possible form and content of a human factors guide to interactive computer system design are as follows:

a. The existing literature relevant to this field is badly fragmented because of its foundation in several different disciplines, and because relevant empirical data include those derived from many studies not specifically dealing with computer systems. Much of this literature is outside of that normally considered by human factors personnel, and the vast majority is outside the range used by interactive system designers. There is a strong need for the development of integrated guidelines.

b. While there is a large body of empirical data relevant to such guidelines, there are many significant gaps. In particular, there is inadequate information to support the development of highly quantitative "reference handbook"-type guidelines, except within certain fairly limited subdomains.

c. Consideration of the problem-solving behavior and information needs of the interactive system designer leads us to believe that "reference handbook" guidelines would not truly satisfy the need anyway. What is needed is a design guide which is largely procedural in nature and is organized around the design process employed by designers.

d. Despite the existing gaps in our knowledge, a design guide of this sort appears feasible. Such an approach is compatible with the presentation of human factors methods, as well as empirical data and specific recommendations. In such a presentation, general psychological knowledge can often be used to advantage, especially in areas in which empirical information is sparse. In areas in which specific recommendations are impossible, this approach can at least direct the designer's attention to relevant factors.

e. Guidelines associated with the early system design process (e.g., user requirements analysis) will necessarily emphasize methods to be employed by the designer. Later, when the design decisions are more concrete and detailed--and concern areas in which more empirical research has been done--the guidelines can be more specific and prescriptive.

f. Although it is feasible to construct a design guide for interactive systems in general, it may be better to develop them for restricted types of systems (e.g., message processing, or tactical information systems). User behavior, and thus, desirable system properties, tend to be highly task-specific. By concentrating on a restricted range of user tasks, it should be possible to make guidelines more prescriptive and explicit, and to use more meaningful examples, as well (pp. 141-143).

The annotated bibliography was searched for sources of guidelines appropriate to the design of user/operator transactions in battlefield automated systems to be more fully developed in the next phase of the project. In Table 4, these sources are identified within the classification scheme of design features presented in Table 1.

Table 4

Sources of Guidelines Relevant to User/Operator Transactions

1. CONTROL METHODS

Author(s)	Specific Topic
Bennett, J.L., 1972	Interactive systems
Chamberlain, R.G., 1975	Interactive system design
Cheriton, D.R., 1976	Man-computer dialogue
Dinter, H., 1969	Computer-based information systems
Donerty, W.J., Thompson, C.M., & Boies, S.J., 1972	Interactive systems--functions, software, linguistics, scheduling
Kennedy, T.C.S., 1974	Interactive dialogue
Martin, T.H., & Parker, E.B., 1971	Interactive systems
Sterling, T.D., 1974	Computers in general
Sterling, T.D., 1975	Computers in general
Stewart, T.F.M., 1976	Man-computer interface
Vaughan, W.S., Jr. & Mavor, A.S., 1972	Functional properties of interactive systems
Wood, R.C., 1972	Interactive systems

1.1 Command Languages

No sources of guidelines specific to command languages were cited.

1.2 Menus

No sources of guidelines specific to menus were cited.

1.3 Function Keys

Dolotta, T.A., 1970	Teletypwriter terminal
Hanes, L.F., 1975	Keyboards
Yllo, A., 1962	Keypunch-data entry

1.4 Hybrid Methods

No sources of guidelines specific to hybrid methods were cited.

1.5 Prompts/HELPS

No sources of guidelines specific to prompts/HELPS were cited.

2. DISPLAY FORMAT

Danchak, M.M., 1976	Display design
Gould, J.D., 1968	CRT display--visual factors
Grether, W.F., & Baker, C.A. 1972	Visual information presentation
Ton, W.H., 1969	Displays
Whitham, G.E., 1965	Display size/resolution

2.1 Fixed Alphanumeric Displays

Buckler, A.T., 1977	Alphanumeric displays
Hayman, E., 1969	CRT alphanumeric displays

2.2 Variable Length Alphanumeric Displays

No sources of guidelines specific to variable length alphanumeric displays were cited.

2.3 Graphic Displays

Barmack, J.E., & Sinajko, H.W., 1966	Interactive graphics
Foley, J.D., & Wallace, V.L., 1974	Interactive graphics

2.4 Highlighting

Christ, R.E., 1975	Color coding-visual displays
Christ, R.E. & Corso, G.M., 1975	Color coding-visual displays

3. DATA ENTRY AND HANDLING

Wallace, V.L., 1976	Graphical input devices

4. MESSAGE COMPOSITION AIDS

Green, E.E., 1976	Message design

4.1 System Design Features

Bryden, J.E., 1969	CRT displays
Cropper, A.G., & Evans, S.J.W., 1968	Display design
	Display design
Jenny, J.A., 1973	Terminals
Stewart, T.F.M., Oestberg, O., & MacKay, C.J., 1974	Terminals

4.2 Format for Alphanumeric Messages

No sources of guidelines specific to format for alphanumeric messages were cited.

4.3 Graphic Messages

No sources of guidelines specific to graphic messages were cited.

5. DATA RETRIEVAL ASSISTANCE

No sources of guidelines specific to data retrieval assistance were cited.

6. GLOSSARIES

No sources of guidelines specific to glossaries were cited.

7. ERROR HANDLING

7.1 Error Prevention

No sources of guidelines specific to error handling were cited.

7.2 Error Detection

No sources of guidelines specific to error detection were cited.

7.3 Error Feedback

No sources of guidelines specific to error feedback were cited.

7.4 Error Correction/Recovery

Varley, T.C., 1969	Error correction checklist

8. USER/OPERATOR CONFIGURATION

Smith, S.L., 1974	User interface

Engle, S.E., and Granda, R.E. *Guidelines for man/display interfaces*, IBM Poughkeepsie Laboratory, Poughkeepsie, New York. 19 December 1975. (TR 00.2720).

This document is, to quote Shneiderman, "the best detailed guide for design of interactive systems (*op cit.*, page 254). The guidelines are specifically to assist a software developer in designing the display interface between a program and intended users but the authors also feel that the guidelines will be useful to hardware developers as well. There is much information which has been of use to this project in initiating the development of a set of guidelines, especially since there is a focus on the user requirements. The authors recognize the limitations of these guidelines:

> The present set of guidelines are not exhaustive. They represent a first-level effort to collect and identify what is known or could reasonably be expected to be deduced from the present state of knowledge. They also provide some insight into those areas which are poorly known or for which little factual data exists. (page 1)

Fortunately, the organizational structure adopted by Engel and Granda, while not consistent with or as comprehensive as that developed for this project, is compatible with the organization shown in Table 1. Thus, much of what these authors have presented is directly applicable to this project's purposes.

Smith, S.L. *Requirements definition and design guidelines for the man-machine interface in C^3 system acquisition*. Mitre Corporation, Bedford, Massachusetts, 31 December 1979. (Mitre Technical Report MTR-3888).

This report explores the status and needs of the man-machine interface (MMI) and comes to the following conclusions and recommendations:

> This report proposes that a significant program of work be undertaken. It marks a beginning, not an end. Thus only tentative, interim conclusions are offered, and the chief recommendation is that the work be carried forward. To follow the approach outlined here, the next steps involve further development of tools for MMI requirements definition and design, and evaluation of the application of those tools in C3 system acquisition.

Three kinds of tools have been proposed:

1. An MMI requirements matrix, a systematic tabulation of the functional capabilities required by different operator tasks, to permit requirements definition in advance of MMI design. The concept of a requirements matrix is described in Section 2 of this report and illustrated in Appendix B. A tentative conclusion is that this requirements matrix could prove a useful tool, at the least providing a check list for systematic consideration of MMI requirements, with some potential promise as an effective means of coordinating analysis with design. Further development of this requirements matrix is recommended in conjunction with evaluation in system acquisition.

2. MMI design guidelines, a compilation of available wisdom, to be tailored to the requirements of different system applications. Design guidelines are discussed in Section 3 of this report and illustrated in Appendix C. A tentative conclusion is that guidelines can be found for the design of certain common MMI functional capabilities, and that these can be related at least approximately to the requirements matrix, with potential for tailoring. It is recommended that the sample set of guidelines presented here be expanded to provide broader functional coverage, and then evaluated in system acquisition.

3. Design documentation, some means of specifying detailed MMI design for coordination and review in advance of software implementation. Design documentation is discussed in Section 4 of this report, and one possible approach is illustrated in Appendix D. A tentative conclusion is that such documentation could prove useful for both initial design and subsequent design modification, but that it is not clear just what are the proper means for imposition of this special documentation requirement in system acquisition. This question should be explored further, until a formal documentation requirement can be developed.

All of these proposed tools must be applied to assess their value. Discussion of the possible utility of these tools for MMI design is an interesting exercise in armchair philosophy, but will have no practical effect unless carried forward and tested in actual system development. Certainly no Air Force or DoD design standard can be justified on the basis of this discussion alone, without practical evaluation (pp. 40 and 41).

One of the Appendices to this report contains a set of design guidelines. Table 5 presents a sample of these guidelines which will be considered in this project's further development of guidelines and criteria.

Table 5

Design Guidelines for Data Entry Functions

Code

2.0 DATA ENTRY/INPUT

- 1 Where data entry is a significant task function, it should be accomplished via the operator's primary display. (For example, entry via typewriter is acceptable only if the typewriter itself, under computer control, is the primary display medium.)

- 2 Data entry transactions, and associated displays, should be designed so that the operator can use one mode of entry as long as possible before having to switch to another (e.g., switching from lightpen to keyboard input).

- 3 Except for passwords and other secure entries, keyed inputs should always appear in the display.

- 4 Keyed data entry and change on an electronic display should generally be accomplished by direct character replacement, in which keyed inputs replace underscores or previous entries (including default values) in defined data fields.

- 5 Wherever possible, data entry should be self-paced, depending upon the operator's needs, attention span and time available, rather than computer processing or external events. (Where self-pacing does not seem feasible, the general approach to task allocation and MMI design should be reconsidered.)

- 6 Using a form-filling dialogue, entry of logically grouped items should be accomplished by a single, explicit action at the end, rather than requiring separate entry of each item.

Smith, S.L. *Man-machine interface (MMI) requirements definition and design guidelines: A progress report*. Mitre Corporation, Bedford, Massachusetts, 30 September 1980. (Mitre Technical Report MTR-8134).

This document extends the work previously presented by Smith. Of particular interest to the project's further development of design guidelines and criteria are an Appendix which presents design guidelines for sequence control

and another Appendix which presents a MMI requirements checklist. The latter is assumed to have potential for the designation of design principles appropriate to different stages of system design. Examples of each set of data are presented below in Table 6 and 7.

Shneiderman, Ben. *Software psychology: Human factors in computer and information systems,* Winthrop Publishers, Inc., Cambridge, Massachusetts, 1980.

This text has become a "standard for the industry" in a very short time. It is addressed to a broad and varied audience: professional system designers, managers, and programmers; advanced undergraduate and beginning graduate students in human factors in computers and information systems; and industrial and academic researchers in computer science, information systems, psychology, and human factors. The book provides a review of a large number of current research topics relevant to the development of design guidelines and criteria for user/operator transactions with battlefield automated systems. The author's intent to provide a psychological perspective to permit increased awareness of the distinctions between people and computers has particular advantage for this project's purposes.

Shneiderman defines software psychology as "the study of human performance in using computer and information systems" (page 5) and identifies the *foci* of software psychology as "ease of use, simplicity in learning, improved reliability, reduced error frequency, and enhanced user satisfaction" (*ibid*). Of most relevance to this project are: (a) the replication of and development of some specific guidelines for programming and systems design, and (b) a "practitioner's summary" which is incorporated into each chapter of the book.

Additional Non-ARI Literature to be Reviewed

In addition to documents previously cited (pages 27 - 29) as relevant to this project, the documents cited on page 41 are judged to have potential utility and will be reviewed as part of a formal, extensive, and substantive literature review.

Table 6

Design Guidelines for Sequence Control

SEQUENCE CONTROL

Objectives:
Minimized control actions by user.
Low memory load on user.
Consistency of control actions.
Compatibility of sequence control with user needs.
Flexibility of sequence control.

3.0 GENERAL

- 1 Flexible means of sequence control should be provided so that the user can accomplish necessary transactions involving data entry, processing, retrieval and transmission, or can obtain guidance as needed in connection with any transaction.

  Example: In scanning a multi-page display the user should be able to go forward or back at will; if the MMI design permits only forward steps, so that the user must cycle through the entire display series to reach a previous page, that design is deficient.

  Comment: Necessary transactions should be defined in task analysis prior to software design.

- 2 Control inputs should be simplified to the maximum extent possible, particularly for tasks involving real-time response, and should permit completion of a transaction sequence with the minimum number of control actions consistent with user abilities.

  Example: The user should be able to print a display directly without having to take a series of other actions first, such as calling for the display to be filed, specifying a file name, then calling for a print of that named file.

  Comment: The software designer should program the computer to handle intervening steps automatically, informing the user what has been done if that seems necessary.

Table 7

MMI Requirements Checklist

Task ______________________ Reviewer ______________ Date ________

MMI Capability	Requirement Estimate* E	U	N	Comment
1.0 DATA ENTRY/INPUT				
1.1. Position Designation				
1. arbitrary positions	.	.	.	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
1 discrete	_	_	_	
2 continuous	_	_	_	
2. predefined positions	.	.	.	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
1. HOME	.	.	.	
1 upper left	_	_	_	
2 center	_	_	_	
3 lower right	_	_	_	
4 other	_	_	_	
2 command entry area				
3 end of file				
4 other				
3. incremental positions	.	.	.	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
1. by character	.	.	.	
1 right	_	_	_	
2 left	_	_	_	
3 up	_	_	_	
4 down	_	_	_	
2. by interval (TAB)	.	.	.	
1 horizontal	_	_	_	
2 vertical	_	_	_	
3. by other features	.	.	.	
1 word	_	_	_	
2 line	_	_	_	
3 paragraph	_	_	_	
4 other	_	_	_	
1.2. Direction Designation				
1 vector rotation	_	_	_	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
2 sequential pointing	_	_	_	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
3 numeric entry	_	_	_	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
4 other	_	_	_	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

*E = Essential, U = Useful, N = Not Needed

Additional Non-ARI Literature to be Reviewed

Borko, H. *Utilization of on-line interactive displays* (Report No. SP-2575). Santa Monica, California: System Development Corp., August 1966. (AD 640652)

Carbonell, J.R., Elkind, J.I., and Nickerson, R.S. On the psychological importance of time in a time-sharing system. *Human Factors*, 1968, 10, 135-142.

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Miller, R.B. Response time in man-computer conversational transactions. *AFIPS Conference Proceedings*, 1968, 33 (pt. 1), 267-277.

Nickerson, R.S. and Pew, R.W. *Oblique steps toward the human factors engineering of interactive computer systems* (Report No. 2190). Cambridge, Mass: Bolt, Beranek and Newman, Inc., July 1971. (Also published as an appendix in M.C. Grignetti, D.C. Miller, R.S. Nickerson, and R.W. Pew, *Information processing models and computer aids for human performance*. Cambridge, Mass: Bolt, Beranch, and Newman, Inc., June 1971). (AD 932913)

Pew, R.W., Rollins, A.M., and Williams, G.A. Generic man-computer dialogue specification: An alternative to dialogue specialists. In *Proceedings, 6th Congress of the International Ergonomics Association*. Santa Monica, California: Human Factors Society, 1976, 251-254.

Strubs, M.H. *Automated aids to on-line tactical data inputting* (Technical Paper 262). Arlington, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, February 1975. (AD A010350)

Wallace, V.L. The sementics of graphic input devices. In Proceedings, ACM Symposium on Graphic Languages, *SIGPLAN Notices*, June 1976, 11(6), 61-65.

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